



Predicting effects of rainforest fragmentation from live trapping studies of small mammals in Sri Lanka

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Abstract: This paper examines the impact of forest fragmentation on small mammals inhabiting the rainforests of Sri Lanka. Fifteen forests ranging in size from 145 to 11000 ha were live-trapped for five to eight nights each in both interior and edge habitats, yielding a total of 18400 trap nights. A total of 444 individuals belonging to 10 species of small mammals were captured. Multiple-regression analysis incorporating three indicators of fragmentation: patch area, shape index (perimeter/area) and degree of isolation, showed no significant effects on overall species richness of small mammals. This is likely because the decline of forest-adapted species from small forest fragments was accompanied by an increase in more tolerant and adaptive species. Patch size, however, had a significant positive effect on the abundance of small mammals. Of the two dominant species, the endemic *Mus mayori* was positively affected by patch area whilst *Rattus rattus* was not affected. Although no differences were evident between interior and edge habitats with respect to total species richness and abundance, endemics were more abundant in core areas while the reverse was true for the non-endemics. Core forest areas were significantly different from forest edges with respect to canopy cover, density of herbaceous vegetation, large trees and litter cover. These results suggest that forest fragmentation is detrimental to some forest specialists and beneficial to some generalists.

Keywords: Edge effects, endemics, fragmentation, rainforests, small mammals, Sri Lanka.

INTRODUCTION

The global decline of biodiversity has been primarily attributed to habitat loss and fragmentation of natural landscapes. Not surprisingly, many studies have focused on the effects of forest fragmentation on the distribution and abundance of different animal taxa (Walters 1991; Boone & Keller 1993; Malcolm 1994). Forest destruction and fragmentation may affect fauna in several ways. As forests become increasingly fragmented the smaller remnant patches support fewer species (e.g. Debinski & Holt 2000; Laurance et al. 2000; Cox et al. 2004). The creation of edge habitats at the interphase where the forest meets man-modified habitats facilitates invasion of competitors or predators and/or exposes forest species to unsuitable external environmental conditions (Yahner 1988); a linear forest would be exposed to greater edge effects than a circular forest patch having the same area. Also, as forests become increasingly isolated, inter-patch migration becomes more difficult. This factor is particularly important for faunal taxa that have a metapopulation structure which necessitates frequent mixing of populations between different forest patches (Diffendorfer et al. 1995). Based on these factors it could be predicted that small, isolated and irregularly-shaped forests would support the lowest faunal diversity. However, all species are not equally sensitive to habitat fragmentation. For example species vulnerability to

forest fragmentation depends on habitat preferences (Andr n 1994). Generalist species, capable of using the original forest, its borders and the surrounding matrix, are less affected than species restricted to the use of the forest alone.

The tropical rainforests in southwestern Sri Lanka harbour a rich complement of flora and fauna, with a large proportion of species being endemic to the island. Because of high levels of endemism and the exceptional levels of threat facing the biota, the wet zone in the southwest of the country has been recognized as a biodiversity hotspot (Myers 1990; Myers et al. 2000). Southwestern Sri Lanka, together with the Western Ghats of India, has the highest human population density among the hotspots (Cincotta et al. 2000). Increasing human settlements, urbanization and agricultural expansion has resulted in intense habitat degradation and fragmentation of the once extensive forests, which now cover a mere eight per cent of Sri Lanka's wet zone land area. So far, no study has attempted to examine the influence of spatial attributes of forest fragments and/or edge effects on the fauna inhabiting these rainforests in Sri Lanka.

The present live trapping study aimed to investigate the effects of forest area, shape, degree of isolation and the edge effects on species richness and abundance of small mammals in rainforest fragments of southwestern Sri Lanka with a view to ascertaining the overall effects of forest loss and fragmentation on this community. Small mammals are of special interest as they make a significant contribution to the country's biological diversity and endemism representing over 30 per cent of the mammals and over 60 per cent of the endemic mammals inhabiting the island.

METHODS

Selected rainforests

A total of 15 rainforests ranging in size from 145 to 11000 ha were surveyed for small mammals from 2006 to 2009 in: Kombala-Kottawa, Kanneliya, Dombagaskanda, Kalugala, Morapitiya, Delwala, Delgoda, Dellawa, Masimbula, Warathalgoda, Kalubowitiyana, Sinharaja, Walankanda, Yagirala and Kudumeriya in the four districts of Ratnapura, Kalutara, Galle and Matara in southwestern Sri Lanka. These are low to mid elevation forests with tropical

wet evergreen forest vegetation (de Rosayro 1950). The forests are dominated by tree species of the family Dipterocarpaceae.

Capturing small mammals

Small mammal communities were assessed using live trapping. Two trapping grids were laid, one at the edge of the forest starting at the boundary (edge habitat) and the other in the forest interior at least 500m away from the forest boundary (core habitat). Each trapping grid consisted of 50 Sherman's live traps laid at 10m intervals and baited with lightly roasted coconut kernel. This method has been successfully used for live trapping small mammals in Sri Lankan rainforests in the past (Wijesinghe & de Brooke 2005). Live trapping was conducted for five to eight nights twice or thrice during the study period yielding a total of 18400 trap nights. A live trapping of four nights has been recognized as being sufficient for the comparison of small mammal communities between forests (Wijesinghe 2010). Traps were checked and rebaited each morning and captured individuals were released at the point of capture after identification. Fur clipping enabled the identification of recaptured individuals within each trapping session of a maximum of eight days. The abundance of each species of small mammal was taken to be the number of new animals captured during each individual trapping session in a given forest, following Wijesinghe & Brooke (2005), Molur & Singh (2009), Ratnaweera & Wijesinghe (2009), and Wijesinghe (2010).

Fragmentation indices

Information on patch size, length of periphery and the distance to the nearest forest fragment for the 15 surveyed forests was obtained from the most recent digital maps provided by the Forest Department, Sri Lanka. If a forest was connected to another forest, the degree of isolation was taken to be zero. The shape index for each of the forests was calculated according to Gkaraveli et al. (2001) where Shape index = Perimeter of fragment / Area of fragment.

Habitat assessments

A total of 10 microhabitat parameters were identified that could be potentially affected by fragmentation in each of the two trapping grids at the edges and core areas of the selected forests. They were

canopy cover, number of seedlings (small plants below the height of ½m), number of non-woody herbaceous plants, number of trees with a girth at breast height (gbh) of less than 20cm, number of large trees (trees with over 20cm gbh), litter depth, litter cover, light intensity, relative humidity and temperature at a height of one metre from the ground. These were measured in six 5x5 m quadrats which were evenly distributed throughout each of the two trapping grids. The canopy was estimated cover using a plastic pipe (sighting tube with a diameter of 2.5cm), one end of which was covered by a piece of cellophane marked with a grid. When looking vertically upwards through the pipe towards the sky, the grid squares in which the view in at least half the area was intercepted by the canopy was counted and used to calculate the percentage canopy cover. Five readings were taken at the four corners and middle of each of the 5x5 m quadrats. The number of seedlings, non-woody herbaceous plants, small trees and large trees were counted within each of the six 5x5 m quadrats. Litter depth was measured at the four corners and middle of each quadrat using a ruler. This also included the humus layer. The litter cover was estimated at the four corners and middle of each quadrat using a square mesh of 25x25 cm with subdivisions of 5x5 cm squares. The number of squares where more than half the square was covered by litter was counted and used to calculate the percentage litter cover. Temperature, relative humidity and light intensities (Yu Pung YF 172) were measured using standard portable meters (Yu Pung YF 180).

RESULTS

The small mammal community in the wet zone forests

A total of 444 individuals belonging to 10 species, eight rodents and two shrews, were recorded from the 15 rainforests. Five of these species *Mus mayori* Thomas, 1915 (Spiny Mouse), *Srilankamys ohiensis* Phillips, 1929 (Sri Lanka Bicolored Rat), *Funambulus layardi* Blyth, 1849 (Flame-striped Jungle Squirrel), *Crocidura miya* Phillips, 1929 (Sri Lanka Long-tailed Shrew) and *Suncus zeylanicus* Phillips, 1928 (Sri Lanka Jungle Shrew) are endemic, with one of them (*S. ohiensis*) belonging to an endemic genus. The non-endemics recorded were *Mus booduga* Gray,

1837 (Field Mouse), *Rattus rattus* Linnaeus, 1758 (Common Rat), *Vandeleuria oleracea* Bennett, 1832 (Long-tailed Tree Mouse), *Funambulus sublineatus* Waterhouse, 1838 (Dusky-striped Jungle Squirrel) and *Funambulus palmarum* Linnaeus, 1766 (Palm Squirrel). The capture rate (number of captures per 100 trap nights) was 3.09 per cent. The two predominant species *M. mayori* and *R. rattus* comprised 90 per cent of the small mammal community.

Effect of forest fragmentation on small mammals

Table 1 shows the summarized results of the trapping survey in the 15 forests. Multiple regressions were conducted incorporating the three indicators of fragmentation, i.e. the area, shape and the degree of isolation of the forests, as independent variables and species richness or abundance as the dependent variable. These analyses revealed that species richness was not significantly affected by any of the three factors (species richness = $-0.242 + 0.000025\text{area} - 0.714\text{shape} - 0.0523\text{isolation}$; $F = 2.76$, $P > 0.05$), but that abundance was significantly and positively affected by patch size (abundance = $2.12 + 0.000148\text{area} - 2.23\text{shape} - 0.161\text{isolation}$; $F = 5.92$, $P > 0.05$). The three fragmentation indices contributed to around 40% of the variation in species richness and to 60% variation in abundance. Contrasting trends were observed with the two predominant species. Multiple-regressions incorporating abundance of the endemic *M. mayori* showed that around 80% of the variation in abundance was explained by the three factors with patch size having a positive and significant influence ($M. mayori = 0.705 + 0.000095\text{area} - 0.846\text{shape} - 0.0947\text{isolation}$; $F = 16.74$, $P < 0.001$). The positive value for area indicates that *M. mayori* is more abundant in larger forest patches than in smaller ones. It should be noted, however, that this species also utilized smaller forest patches to a certain extent (Table 1). Although not significant, the shape index had a negative impact on this species indicating that it preferred more circular patches. In the case of the other predominant species *R. rattus*, only 10% of the variation was explained by the three factors, with none of the factors having a significant impact ($R. rattus = 1.43 - 0.000025\text{area} - 1.07\text{shape} - 0.117\text{isolation}$; $F = 0.43$, $P > 0.05$). In the case of this too shape had a negative value indicating that it prefers circular forest patches. With regards to the Shannon-Weiner Diversity Index [$H' = -\sum(P_i \ln P_i)$]

Table 1. Area, shape and distance to the nearest forest fragment of the selected forests and the species richness (S), abundance (number of species/individuals captured per 100 trap nights), abundance of the two predominant species *Mus mayori* (Mm) and *Rattus rattus* (Rr) and the diversity (H') and evenness (E) values of the small mammal community of the fifteen rainforests. H' and E values are from the Shannon-Wiener Diversity Index.

Forest	Area (ha)	Shape Index	Distance to the nearest forest (km)	S	Abundance			H'	E
					Total	Mm	Rr		
Kanneliya	6143.0	0.007	0.00	0.47	3.33	1.27	1.53	1.26	1.42
Kottawa	2108.0	0.034	0.23	0.18	2.09	0.91	1.18	0.68	2.27
Dombagaslanda	449.0	0.024	0.00	0.18	1.55	0.64	0.91	0.68	2.27
Kalugala	4835.0	0.018	0.77	0.27	2.36	1.18	1.09	0.83	1.73
Morapitiya	7108.0	0.010	0.84	0.27	3.18	1.45	1.55	0.81	1.69
Delwala	1531.0	0.015	0.00	0.36	2.00	0.73	1.09	0.98	1.63
Delgoda	1013.4	0.218	0.00	0.14	1.93	0.64	1.29	0.64	2.13
Dellawa	2231.5	0.018	0.00	0.21	2.79	1.07	1.64	0.77	1.6
Masimbula	299.2	0.004	0.45	0.29	2.43	0.71	1.57	0.48	0.8
Warathalgoda	1940.0	0.026	0.00	0.36	2.73	1.09	1.45	0.93	1.55
Kalubowitiyana	145.0	0.068	2.50	0.29	1.36	0.36	0.86	0.95	1.58
Sinharaja	11000.0	0.009	0.00	0.57	3.14	1.57	0.71	1.49	1.66
Walankanda	938.9	0.030	0.00	0.14	1.57	0.43	1.14	0.59	1.96
Yagirala	2999.8	0.015	1.30	0.63	2.50	0.75	1.13	1.31	1.86
Kudumeriya	2152.0	0.014	0.45	0.36	3.18	1.00	1.91	0.94	1.57

or evenness ($E=H'/\log S$) where P_i is the proportional abundance of a species in a forest and S is the species richness in that forest, the values show that Kanneliya, Sinharaja and Yagirala had distinctly higher diversity compared to the other forests (Table 1). In some forests (e.g. Dombagaskanda, Delgoda and Kottawa) although the diversity was low, the evenness values were high suggesting that the existing species were equally distributed.

Table 2 shows the abundance of the individual species in core and edge habitats of the 15 rainforests surveyed during the present investigation. Comparing the core and edge habitats of the forests, a total of eight species of small mammals were recorded from both core and edge habitats (Table 2). Of the 10 small mammals recorded, six species, the endemics *S. ohiensis*, *M. mayori* and *C. miya* and the non-endemics *R. rattus*, *F. sublineatus* and *F. palmarum*, were recorded from both core and edge habitats, while *F. layardi* and *S. zeylanicus* were recorded from only the core areas and the nonendemics *M. booduga* and *Vandeleuria oleraceae* were recorded only from edge habitats. With respect to overall abundance, both core areas and edges of forests recorded almost similar numbers of individuals (234 and 210). Similar results

were noted for the abundance of small mammals in core and edge habitats when individual forests were considered ($T=1.34$, $p>0.05$, Pairwise t-Test). Marked differences were nevertheless evident when comparing the abundance of endemics and non-endemics. The abundance of endemics was higher in core areas than in the edge forests (123 core and 69 edge). This is primarily because of the differential use of interior and edge habitat by the endemic *M. mayori*. Significantly higher numbers of individuals were recorded for this species in core habitats (104 individuals) than at the edges (65 individuals). A reverse trend was seen for the non-endemics with more non-endemics using edges than interior areas. Some microhabitat features differed greatly between edges and core areas (Table 3). The core forest areas were characterized by a greater number of large trees, greater canopy cover, and by being shadier, cooler and more humid than the forest edges. The interior areas had a lower litter cover than edges. The forest edges, since they are exposed, have higher light levels and greater herbaceous vegetation. Statistical analyses revealed that four variables namely canopy cover, herbaceous cover, the number of large trees and litter cover differed significantly between the core and edge areas of the forest.

Table 2. Species richness (S) and abundance (A) of the small mammal community and of the individual species in core areas and forest edges (in parentheses) of the 15 rainforests.

Forest	Trap nights	S	A	Mm*	Mb	So*	Rr	Vo	Fl*	Fs	Fp	Cm*	Sz*
Kanneliya	500	7	30	13	-	2	11	-	1	1	-	1	1
		(3)	(20)	(6)		(1)	(12)					1	
Kottawa	500	2	13	7	-	-	6	-	-	-	-	-	-
		(2)	(10)	(3)			(7)						
Dombagaslanda	500	2	9	4	-	-	5	-	-	-	-	-	-
		(2)	(8)	(3)			(5)						
Kalugala	500	3	15	8	-	-	6	-	-	-	-	1	-
		(2)	(11)	(5)			(6)						
Morapitiya	500	3	21	11	-	2	8	-	-	-	-	-	-
		(2)	(14)	(5)			(9)						
Delwala	500	2	12	5	-	-	6	-	-	(1)	-	-	-
		(4)	(10)	(3)	(2)		(4)				(1)		
Delgoda	800	2	15	5	-	-	10	-	-	-	-	-	-
		(2)	(12)	(4)			(8)						
Dellawa	800	2	15	8	-	-	7	-	-	-	-	-	-
		(3)	(24)	(7)			(16)			(1)			
Masimbula	800	3	17	6	-	1	10						
		(3)	(17)	4			(12)				(1)		
Warathalgoda	500	2	16	8	-	-	8	-	-	-	-	-	-
		(4)	(14)	(4)	(1)		(8)					(1)	
Kalubowitiyana	800	3	9	2	-	-	6	-	-	-	1	-	-
		(3)	(10)	(3)			(6)					(1)	
Sinharaja	800	7	36	15	-	3	5	-	2	2	-	2	1
		(4)	(14)	(7)		(1)	(5)				(1)		
Walankanda	800	2	8	3	-	-	5	-	-	-	-	-	-
		(2)	(14)	3			(11)						
Yagirala	800	2	7	4	-	-	3	-	-	-	-	-	-
		(5)	(13)	(2)	(1)		(6)	(1)			(3)		
Kudumeriya	500	4	17	5			10				1	1	
		(3)	(18)	(6)			(11)				(1)		

Mm - *Mus mayori*; Mb - *Mus booduga*; So - *Srilankamys ohienensis*; Rr - *Rattus rattus*; Vo - *Vandeleuria oleraceae*; Fl - *Funambulus layardi*; Fs - *F. sublineatus*; Fp - *F. palmarum*; Cm - *Crocidura miya* and Sz - *Suncus zeylanicus*. * - Endemic species

DISCUSSION

The present survey was conducted with the objective of investigating the overall effects of forest fragmentation on small mammal communities inhabiting the remnant rainforest patches in Sri Lanka. The theory of island biogeography by MacArthur & Wilson (1967) predicts that larger areas would support greater numbers of species and individuals than smaller areas. Supporting this claim, Goodman

& Rakotondravony (2000) report that in Madagascar, the species of the families Tenrecidae and Soricidae declined progressively with diminishing forest size. Similarly, Schoener (1974) proposed that, for small mammals, space is the main niche dimension that facilitates the coexistence of ecologically similar species. It has been shown that larger spaces result in greater resource diversity making the coexistence of a large number of species feasible (Vieira & Monteiro-Filho 2003; Renata 2004). Also, it is reported that

Table 3. Habitat variables (mean \pm std. error) in core and edge habitats in the surveyed rainforests. Results of the pairwise t-Tests comparing the mean values of each parameter in core and edge habitats of the individual forests are also shown.

Habitat feature	Core	Edge	n	T	P
% Canopy cover	93.57 \pm 1.22	89.78 \pm 1.60	15	2.14	0.050*
Number of seedlings	15.94 \pm 2.24	15.22 \pm 2.66	15	0.56	0.583
Number of herbs	29.35 \pm 4.88	41.70 \pm 5.32	15	-3.64	0.003**
Number of plants	53.00 \pm 6.28	51.40 \pm 8.94	15	0.45	0.662
Number of large trees	6.40 \pm 0.50	4.50 \pm 0.48	15	4.34	0.001***
Litter depth	2.81 \pm 0.11	2.56 \pm 0.17	15	1.37	0.190
% Litter cover	93.48 \pm 1.84	95.86 \pm 1.00	15	- 2.16	0.050*
Light intensity	548.5 \pm 73.5	621.3 \pm 60.5	13	-1.43	0.178
Relative humidity	84.84 \pm 1.62	83.93 \pm 1.46	11	-1.93	0.082
Air temperature ($^{\circ}$ C)	25.2 \pm 0.45	25.9 \pm 0.37	11	1.15	0.263

* = $P < 0.05$; ** = $P < 0.01$; *** = $P < 0.001$

the reduction of species is such that the complement of species in smaller patches is a subset of that found in larger ones (e.g. Patterson & Brown 1991; Pattanavibool & Dearden 2002).

The species-area relationship per se, however, does not consider a variety of other factors that are of considerable importance in determining the viability of species and populations within habitat islands. For instance, fragmentation facilitates the creation of edge habitats that in turn may seriously affect the diversity of organisms within the forest patches (Laurance 1991; Hansen et al. 1992). The type of habitat matrix surrounding the individual forest patches will also have an impact on diversity (Renata 2004). The degree of isolation also influences the viability of the species within a particular fragment (Kozakiewicz & Jurasinska 1989). Hence, the variability of these factors between forest fragments may serve to mask the effects of area on biotic communities. This is evident from the results of several studies - Lindenmayer et al. (2000) for mammals; Wethered & Lawes (2003) for birds; Conde & Rocha (2006) and Rosenblatt et al. (1999) for small mammals.

The present study did not provide direct evidence for the species-area relationship. It is apparent from the results of the present study that the lack of a species-area relationship for the overall small mammal community is because the absence of, or the reduction in, certain species in smaller fragments was well compensated for by other species. These "replacement species", are those that are more adaptable to man modified landscapes. This observation suggests that

a species replenishment model, demonstrated in some studies (e.g. Harraington et al. 2001; Castelletta et al. 2005), is applicable to the rainforests in Sri Lanka. Several studies have in fact shown that the species-area theory may be applicable at a regional scale but is not applicable at smaller spatial scales (Cutler 1991; Patterson & Brown 1991). Middleton & Merriam (1983), working with small mammal fauna of forest fragments in Illinois, likewise claim that the island biogeography analogy does not apply well for the areas studied.

Species replacement tends to obscure species-area relationships. The patterns of replacement of species in smaller fragments in turn reflect the species' ability to tolerate edge effects (Yáñez et al. 1999). Andrén (1994) reports that species' responses to habitat disturbance are varied with fragmentation and edge effects imposing major threats to the survival of forest-dependent fauna. He further states that habitat generalists were largely tolerant of habitat fragmentation, their abundance being similar in forests, corridors, and remnants, and are capable of persisting in remnants only a few hectares in extent. In the present study the patterns of occupancy of the two predominant species, the endemic *M. mayori* and the cosmopolitan *R. rattus* in particular, clearly demonstrate such differences in tolerance. The fact that the smallest fragments and forest edges were occupied by a lesser number of individuals of *M. mayori* strongly suggests that environmental conditions in edges were perceived as matrix rather than a forest habitat by this species. It was evident from the results of the present

investigation that the forest interior was much cooler and had different vegetation characteristics such as greater canopy cover and larger trees and lesser herbaceous cover, than the edge habitats. *R. rattus*, in contrast to the former, is a ubiquitous generalist species that has managed to colonize six continents and thousands of islands in the wet tropics as well as in arid environments. In addition to *M. mayori*, the fact that the endemics *S. ohiensis* and *F. layardi* and the non-endemic *F. sublineatus* preferentially utilized interior areas, suggest that they may be negatively affected by the creation of habitat edges. On the other hand, those that are tolerant of habitat edges and perhaps benefit by such human modifications are *R. rattus*, *M. booduga* and *F. palmarum*.

Due to edge effects and the differential tolerance of species, the shape of a particular forest patch could be expected to influence the biotic community it supports. Circular forest patches will have proportionately less edge habitat than similar-sized linear forest patches (Bentley et al. 2000). The shape index for forest fragments is calculated as the ratio of perimeter to area (Gkaraveli et al. 2001), which increases as forests become more linear. Based on this premise, the abundance of core forest species should be negatively affected by the shape index, which was observed for *M. mayori*.

Although the fragmentation of Sri Lankan rainforests may not have an overall impact on the species richness of the small mammal community the study clearly demonstrates that it may lead to the decline of certain forest-adapted species. This emphasizes the need to preserve large intact and circular forests whenever possible. The preservation of the smaller forests is also important, since they function as potential “stop over points” that may facilitate the spreading of forest species to nearby patches. Such linkages between forests are particularly important for small mammals that are unable to cover large distances.

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